Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Public Safety and Homeland Security Bureau Seeks Comment on Vertical (Z-Axis) Accuracy Metric Proposed by the Nationwide Wireless Carriers	)	PS Docket No. 07-114

COMMENTS OF NEXTNAV, LLC

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SUMMARY

The Stage Z test bed provided the fourth opportunity for NextNav to demonstrate that its Metropolitan Beacon System ("MBS") technology provides vertical location accuracy of within 3 meters for at least 80 percent of wireless calls to E911 emergency services. Specifically, the Stage Z Report indicates that NextNav's MBS technology was accurate within 1.8 meters across all three morphologies tested. These results are fully consistent with the vertical location capabilities that NextNav demonstrated during previous independently managed tests conducted by CSRIC, CTIA and others in 2012, 2013, 2016 and now in 2018.

Given the demonstrated capabilities of NextNav's MBS technology, combined with the test results of another vertical location technology vendor, the Commission should immediately address the critical public safety concern identified by the first responder community by adopting a vertical location metric that truly reflects 'floor level' accuracy, *i.e.*, +/-3 meters for 80 percent of wireless calls to E911. The Commission should reject the request of the major wireless carriers for a vertical location metric of +/-5 meters. Such a metric is not necessitated by the Stage Z test data and would not provide the floor level accuracy that both the wireless carriers and the Commission committed to achieving in the carriers' Roadmap and in the Commission's 2015 *Fourth Report and Order*.

The Stage Z test process provided sufficient information for the Commission to adopt a z-axis metric of +/-3 meters. As the Stage Z Report acknowledges, the vertical location tests were conducted in a "reasonably comprehensive" selection of regions, buildings, test points and weather conditions and no material variations in performance were identified. The test set up reflected real world conditions, using a variety of handsets and operating systems, including both older and newer devices. The barometric pressure sensors contained within those handsets are commercially

available and widely used by manufacturers, having been installed in the handsets by the device manufacturers and therefore were never touched by any entity involved in the test process.

No further vertical location testing is needed before the Commission adopts its z-axis metric. In fact, any significant delay in the adoption of the metric could harm public safety by placing into question the ability of the major wireless carriers to implement vertical location solutions in the top 25 and 50 census metropolitan areas by the respective 2021 and 2023 deadlines.

This said, NextNav agrees with the carriers that further z-axis testing should be conducted, particularly to assess the capabilities of new vertical location technologies as they are made available by other vendors. Such z-axis testing will need to consider the specific variables and uncertainties that are presented by such location technologies. Thus, just as the testing of barometric sensor technologies considered variations in outdoor and indoor air pressure, the testing of location technologies that rely on registered databases of consumer devices (such as Wi-Fi and Bluetooth) will have to consider variations in the density and transmission characteristics of such devices in different types of buildings and socioeconomic conditions.

Most importantly, the Commission should not wait for the introduction of additional technologies before adopting a z-axis metric that ensures floor level accuracy for emergency first responders. The multiple rounds of independent testing that have already been conducted clearly demonstrate the availability of multiple indoor location technologies that can reliably provide floor level vertical location accuracy. The anticipated availability of other location technologies will simply provide further options for wireless carriers in addition to the barometric pressure based technologies made available by NextNav and others, and in addition to the dispatchable location solutions that the wireless carriers are developing through the National Emergency Address Database and other resources.

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NextNav, LLC ("NextNav"), by its attorneys, hereby responds to the Commission's Public Notice[1] seeking comment on the vertical accuracy metric that should be adopted given the Commission's recognition of "the importance and need for floor-level location information to be provided to emergency responders."[2]

The Commission's Public Notice follows the completion of the Stage Z test bed, which, like test beds before it, demonstrated the technical capability to produce highly accurate location information for wireless callers to E911 emergency services, including vertical floor level information that is necessary to locate callers expeditiously in large structures. NextNav was pleased to have participated in the Stage Z test bed, just as it participated in each of the test beds before it.

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[1] Public Safety and Homeland Security Bureau Seeks Comment on Vertical (Z-Axis) Accuracy Metric Proposed by the Nationwide Wireless Carriers, PS Docket No. 07-114, DA 18-928 (Sept. 10, 2018) ("*Vertical Metric Public Notice*").

[2] Wireless E911 Location Accuracy Requirements, *Fourth Report and Order*, 30 FCC Rcd 1259, ¶ 112 (2015) ("*Fourth Report and Order*").

The Stage Z test bed reaffirmed the significant accuracy of NextNav's Metropolitan Beacon System ("MBS") technology, documenting vertical location accuracy of 1.8 meters or better for 80 percent of fixes and 3 meter or better accuracy for 94 percent of fixes, *i.e.*, floor level accuracy. A second vendor, Polaris, also demonstrated vertical location technology during the Stage Z test bed. Given these and prior test results, the Commission is clearly justified in concluding that it would be appropriate and highly beneficial to the public interest to adopt a z-axis metric of +/-3 meters for 80 percent of wireless calls to E911.

Despite this fact, the major wireless carriers have proposed a z-axis metric of +/-5 meters for 80 percent of calls.[3] Such a proposal would not provide the floor level accuracy that the public safety community has repeatedly indicated is necessary to ensure that wireless callers to E911 can be located rapidly. A vertical accuracy metric of +/-5 meters is also not justified by the results of multiple rounds of testing that have been conducted since the Commission's initiation of this proceeding. Therefore, the Commission should disregard the proposal of the major wireless carriers and adopt a vertical accuracy metric of +/-3 meters for 80 percent of calls in order to meet the documented needs of the public safety community in aiding and protecting the public.

I. THE STAGE Z TEST RESULTS CONFIRM THAT VERTICAL LOCATION CAN BE DETERMINED WITHIN THREE METERS ON A RELIABLE AND CONSISTENT BASIS

NextNav has repeatedly demonstrated the significant capabilities of its MBS technology in multiple independently-conducted tests. NextNav has been developing its MBS technology for nearly a decade and first demonstrated its capabilities six years ago in the San Francisco Bay Area

[3] *See* Letter from Scott K. Bergmann, Senior Vice President of Regulatory Affairs, CTIA, *et al.*, to Marlene H. Dortch, Secretary, Federal Communications Commission, PS Docket No. 07-114 (Aug. 3, 2018) ("*CTIA Letter*").

as part of the Commission's CSRIC III advisory council's industry-wide independent testing program for E911 indoor location technologies.[4] Using prototype receivers equipped with low-cost, commercially-available barometric pressure sensors, NextNav demonstrated floor level location capabilities in tests that were conducted under the control and direction of CSRIC III.

The positive test results for multiple vendors during CSRIC III's indoor location testing program led directly to the Commission's adoption in 2014 of its Third Further Notice of Proposed Rulemaking on wireless indoor location accuracy.[5] Although the rulemaking focused primarily on improving horizontal accuracy for E911 callers in indoor locations, the rulemaking observed that "[l]ocating 911 callers in a three-dimensional environment has been a longstanding goal of the Commission"[6] because "[v]ertical location information on a caller's floor height would substantially benefit first responders trying to locate callers in multi-story buildings."[7]

The Commission's *Third Further Notice* also acknowledged the CSRIC III test results, which showed that NextNav's initial deployment of its MBS technology could already provide "vertical location accuracy within 2.9 meters and 4.8 meters for the 67th and 90th percentiles, respectively."[8] The *Third Further Notice* additionally observed that a second generation of NextNav's MBS technology was independently tested a second time in 2013 and demonstrated

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[4] *See* CSRIC III WG3, Indoor Location Test Bed Report (Mar. 14, 2013), at 8-9, *available at* http://transition.fcc.gov/bureaus/pshs/advisory/csric3/CSRIC_III_WG3_Report_March_%202013_ILTestBedReport.pdf (last visited Sept. 18, 2018) ("*CSRIC Indoor Location Test Bed Report*").

[5] *See* Wireless E911 Location Accuracy Requirements, *Third Further Notice of Proposed Rulemaking*, PS Docket 07-114, FCC 14-13 (Feb. 21, 2014) ("*Third Further Notice*").

[6] *Id.* ¶ 66.

[7] *Id.* ¶ 65.

[8] *Id.* ¶ 71 (*citing CSRIC Indoor Location Test Bed Report* at 39).

improvements on the results reported in the 2012 test bed, including improvements in z-axis performance.[9]

Specifically, as NextNav's reported to the Commission in 2013, its second generation MBS technology could reliably provide vertical location information within an accuracy range of 1 to 2 meters for at least 67 percent of E911 calls regardless of morphology.[10] The wireless carriers subsequently provided NextNav the opportunity to demonstrate the significant vertical location capabilities of its MBS technology a third time, conducting z-axis testing of NextNav's MBS technology during the Stage 2 test bed that was held in the fall of 2016. The independent test bed administrator indicated that NextNav's MBS technology was accurate within 1.7 meters across the three morphologies tested.[11] The results of the three rounds of independent tests that were conducted on NextNav's MBS technology prior to the Stage Z test bed are provided in Table 1 below.

[9] *Id. (citing* Letter from Bruce A. Olcott, Counsel, NextNav, LLC, to Marlene H. Dortch, Secretary, FCC, PS Docket No. 07-114 (filed Aug. 14, 2013) ("*NextNav Aug. 14, 2013 Ex Parte Letter*") (reporting the test results for a second generation of NextNav's technology)).

[10] *NextNav Aug. 14, 2013 Ex Parte Letter* at 8.

[11] *See Report on Stage Z*, 911 Location Test Bed, LLC PS Docket 07-114, at 126 (Aug. 3, 2018), *included as attachment to CTIA Letter* ("*Stage Z Report*").

Table 1. NextNav's 2012, 2013 and 2016 Vertical Test Results (in meters)

Morphology	Testing Event	67%	80%	90%
Dense Urban	2016 Stage 2 Test Bed	1.1	1.5	2.2
	2013 MBS Rev 2 Tests	2.3	3.2	4.5
	2012 CSRIC III Tests	2.9	3.4	4.0
Urban	2016 Stage 2 Test Bed	0.6	0.8	1.1
	2013 MBS Rev 2 Tests	1.8	2.2	2.7
	2012 CSRIC III Tests	1.9	2.3	2.8
Suburban	2016 Stage 2 Test Bed	2.0	2.3	2.7
	2013 MBS Rev 2 Tests	1.5	2.3	2.9
	2012 CSRIC III Tests	4.6	5.0	5.5
Rural	2012 CSRIC III Tests	0.7	0.9	1.1

Given the significant capabilities of NextNav MBS technology, the growing presence of barometric pressure sensors in smartphones, and based on reports from other technology vendors that they too are developing similar granular vertical location capabilities,[12] the Commission proposed in its *Third Further Notice* to adopt a vertical accuracy requirement of 3 meters for 67 percent of indoor wireless 911 calls within three years, increasing to 80 percent of indoor wireless 911 calls within five years.[13] The Commission observed that, by adopting a 3-meter measurement, the Commission would be "effectively requiring floor level information."[14] The Commission also

[12] *See, e.g.,* Comments of Polaris at FCC Workshop on E911 Phase II Location Accuracy at 3 (Nov. 18, 2013) (*available at* http://www.youtube.com/watch?v=Kt3lWv_oXNY (*last visited* Sept. 18, 2018) (estimating that its vertical location accuracy performance "should achieve floor-level precision across all indoor environments" by the 2016 to 2018 timeframe).

[13] *See Third Further Notice*, ¶ 74.

[14] *Id.* The Commission observed that average floor height of a multi-story building floor is 3.1 meters in residential buildings, 3.9 meters in office buildings, and 3.5 meters in mixed-use settings. *See* Council on Tall Building and Urban Habitat, Height Calculator, *available at*

observed that "[a] vertical search ring greater than 3 meters from the caller could lead to mistaken floor identification."[15]

Consistent with these observations, the Commission concluded in its *Fourth Report and Order* that "it is reasonable to establish a z-axis metric standard for vertical accuracy as an alternative to providing floor-level accuracy by means of dispatchable location."[16] Rather than immediately adopt its proposed 3 meter floor level requirement for vertical location capabilities, however, the Commission agreed to adopt a far more gradual process that was outlined by the major wireless carriers in a document they described as a Roadmap.[17] Specifically, the Commission directed the major wireless carriers to conduct an independently administered and transparent test bed process and, based on the test results, develop and submit a proposed z-axis accuracy metric for the Commission's consideration.[18] The Commission also directed that, if the wireless carriers are unable to implement a dispatchable location approach, they must comply with

http://www.ctbuh.org/TallBuildings/HeightStatistics/HeightCalculator/tabid/1007/language/en-GB/Default.aspx (last visited Sept. 18, 2018).

[15] *Third Further Notice*, ¶ 74.

[16] *Fourth Report and Order*, ¶ 113.

[17] *See* Letter from John Wright, APCO International, *et al.*, to Marlene H. Dortch, Secretary, Federal Communications Commission, PS Docket No. 07-114 (Nov. 18, 2014) ("*Roadmap Cover Letter*"), Attachment A, "Roadmap for Improving E911 Location Accuracy" ("*Roadmap*"), available at https://ecfsapi.fcc.gov/file/60000986637.pdf (*last visited* Sept. 18, 2018). The Roadmap was subsequently amended twice by the wireless carriers in response to various comments. *See* AT&T, Sprint, T-Mobile, and Verizon *Ex Parte* Letter at 3 ("Amended Roadmap") (filed Jan. 21, 2015); APCO, AT&T, CTIA, NENA, Sprint, T-Mobile USA, and Verizon *Ex Parte* Letter (filed Jan. 23, 2015) (modifying certain aspects of the Amended Roadmap).

[18] *Id.* ¶ 116.

the resulting vertical location metric in each of the top 25 census metropolitan areas ("CMAs") within six years and in each of the top 50 CMAs within eight years.[19]

The z-axis test bed was conducted in three cities—San Francisco, Atlanta and Chicago—using wireless location technology provided by NextNav and Polaris Wireless.[20] As noted above, the test results affirmed the findings of the previous three rounds of independent tests that NextNav's MBS technology could reliably and consistently achieve floor level accuracy for very high percentages of indoor wireless calls to E911 emergency dispatchers. The Stage Z test bed documented vertical location accuracy for NextNav's technology of 1.8 meters or better for 80 percent of fixes and 3 meters or better accuracy for 94 percent of fixes, thus confirming that floor level vertical accuracy can be reliably provided.

In addition, the Stage Z report documented vertical location test results for a technology developed by Polaris Wireless that also uses barometric pressure sensors, but did not employ active calibration of the barometric sensors during the test process.[21] The Stage Z Report acknowledges that the test results for Polaris "may underestimate the performance results that might be achieved" if a calibration approach had been employed.[22] Polaris separately indicated that it will use active sensor bias compensation in real world conditions, thus making it appropriate to account for this capability in testing.[23] Given these facts, it is reasonable and appropriate to conclude that the Stage Z test process confirmed, once again, that existing location technologies available from multiple

[19] *Id.* ¶ 117.

[20] *See Stage Z Report* at 3.

[21] *See id.* at 51.

[22] *Id.* at 51.

[23] *See id.* at 133-134 (separate statement of Polaris Wireless).

vendors can reliably achieve floor level vertical accuracy within +/-3 meters for at least 80 percent of wireless calls to E911 emergency services. Therefore, the Commission is not only justified, but arguably obligated pursuant to its statutory mandate to further the public interest, to adopt a vertical accuracy metric of +/-3 meters for 80 percent of calls and to require the major wireless carriers to implement these capabilities within the top 25 CMAs by April 2021 and within the top 50 CMAs by April 2023.

A. The Stage Z Report Provided Sufficient Information to Assess the Performance of the Specific Vendors, Location Technologies, and Mobile Devices that Were Tested in Stage Z

In order to determine the *sufficiency* of the test data produced in any comprehensive test process, it is necessary to consider the *consistency* of the test data. As detailed in the Stage Z Report, the test data produced in the test process showed a very high level of consistency, including consistency between the test locations, between morphologies, between the mobile handsets tested (both by brand and by age), and as compared to the results of the three prior rounds of independently-conducted tests. Therefore, it can appropriately be concluded that sufficient information was produced by the Stage Z test bed for the Commission to identify a z-axis accuracy metric and no further test data is needed.

The Stage Z Report details the consistency of the test data. First, with respect to the geographic locations chosen, NextNav's MBS technology showed a very high level of consistency between San Francisco and Atlanta despite the use of a wide range of morphologies and indoor environments. This is depicted in Figure 1 below.

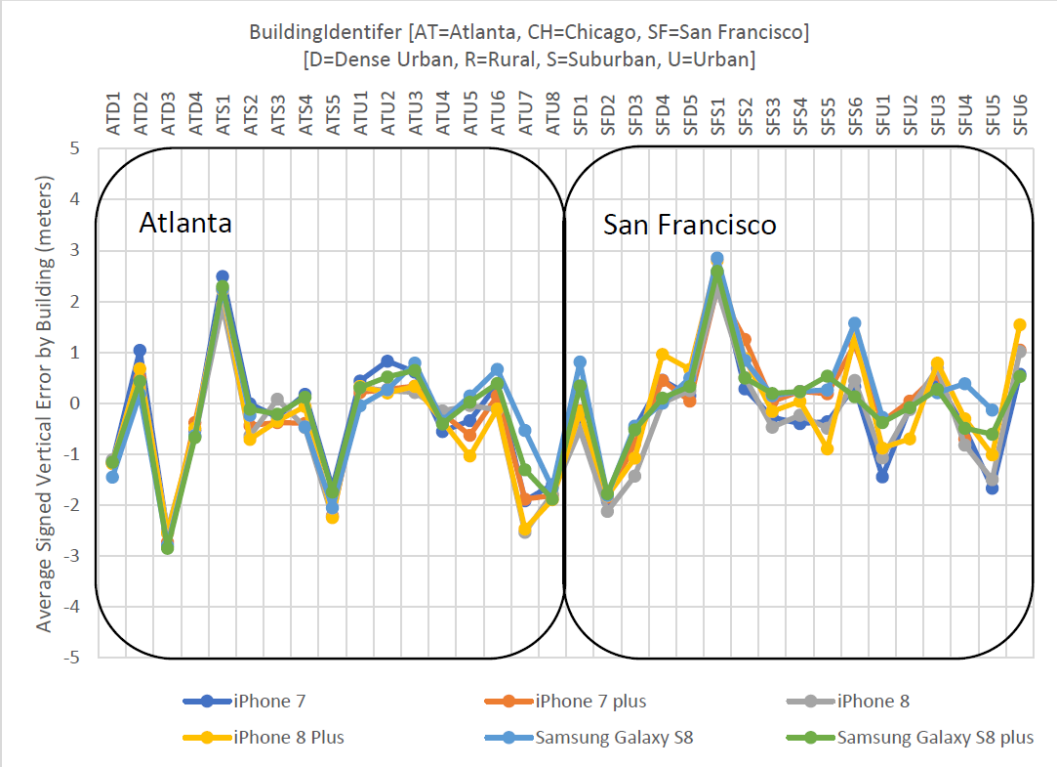

Figure 1. Average Signed Vertical Error by Building – NextNav Devices

The carriers have argued that NextNav's vertical location test results might have been different if NextNav's MBS technology had also been tested in Chicago,[24] where NextNav has not yet deployed an MBS network. NextNav would have been willing to test in that environment if sufficient notice was given to enable NextNav to construct its network in that market. However, Polaris' location technology was tested in Chicago, and, as shown in Figure 2 below, the test results for Polaris' indoor location technology in Chicago were consistent with—if not slightly better than—Polaris' test results for San Francisco. Therefore, no basis exists to argue that the consistency of NextNav's results might have been different if NextNav's MBS technology had also been tested in Chicago.

[24] *See CTIA Letter* at 3.

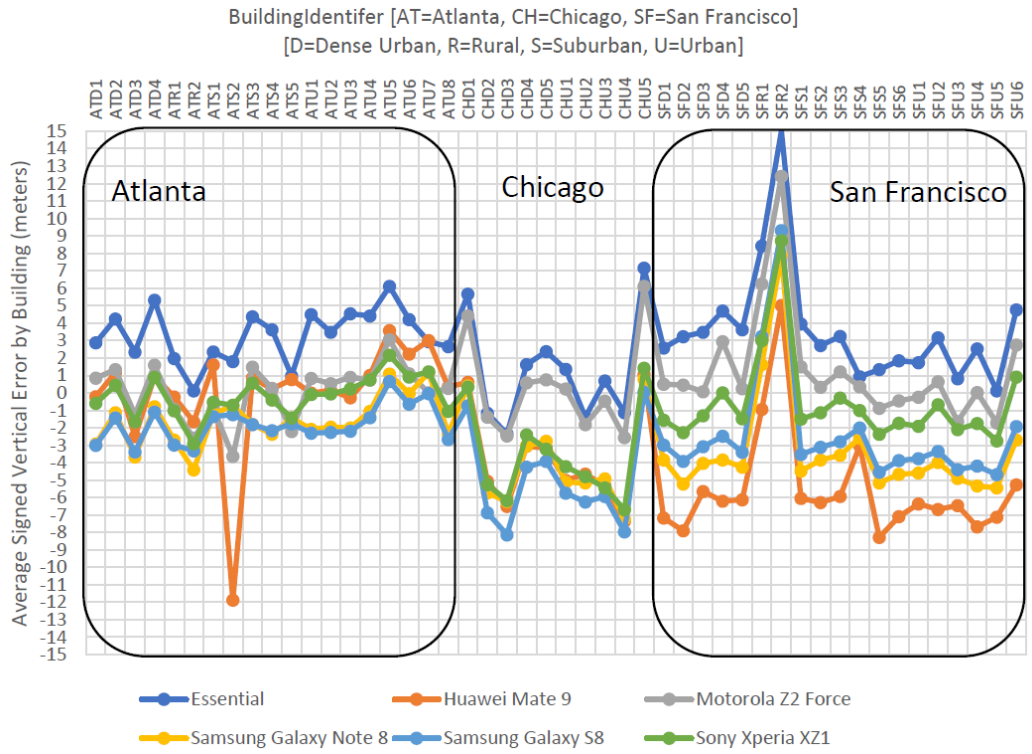

Figure 2. Average Signed Vertical Error by Building – Polaris Wireless Devices

The Stage Z test results also showed a very high level of consistency between morphologies. NextNav's MBS technology was tested in both San Francisco and Atlanta in Dense Urban, Urban, and Suburban environments and, as indicated in Figure 3 below, the variations in the vertical location results were not significant.

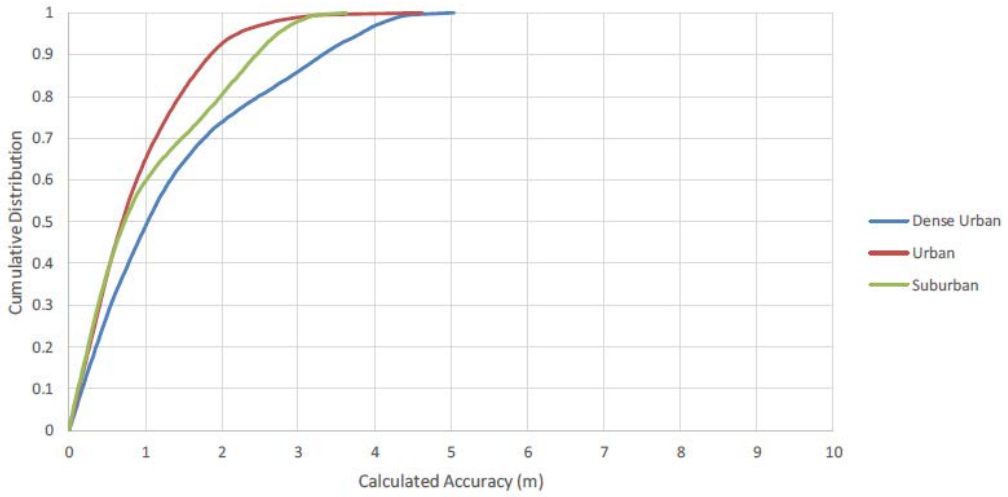

Figure 3. NextNav Vertical Accuracy Cumulative Distribution Function ("CDF") per Morphology

The Stage Z test results also showed a very high level of consistency between different models of handsets, including both older handsets and newer handsets. As depicted in Figure 4 below (which depicts the individual handset results for NextNav's technology in San Francisco), there was not a statistically significant difference between the test results for each of the six handset models that were used in the tests.

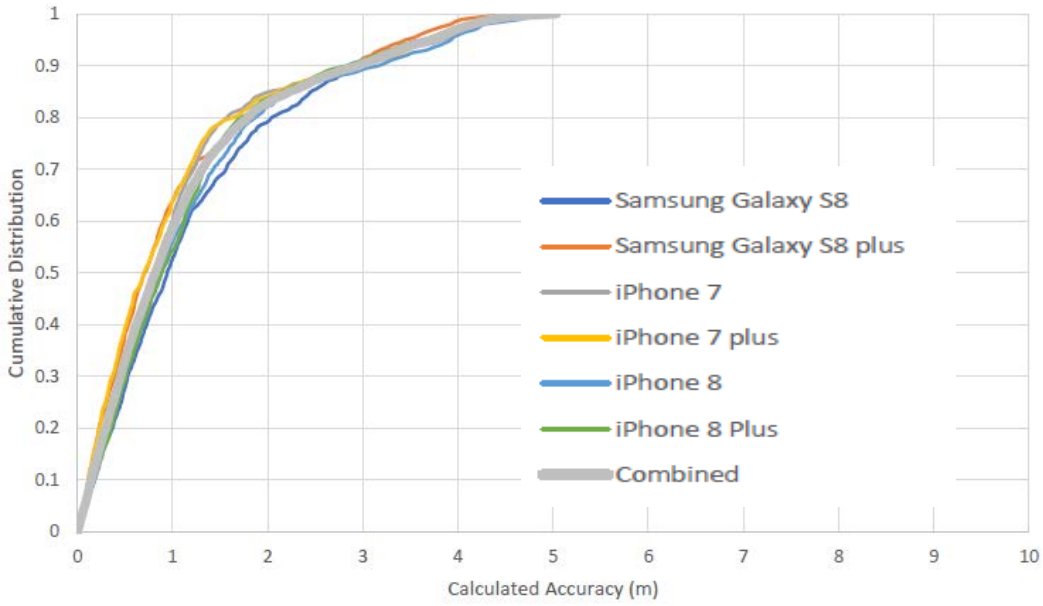

Figure 4. NextNav San Francisco Dense Urban Aggregate and Per Handset Vertical Accuracy CDF

Finally, the Stage Z test results showed a high level of consistency as compared to the results of prior independent tests that have been conducted on NextNav's MBS technology. As noted in the previous section of these comments and detailed in Table 2 below, NextNav's technology demonstrated vertical location accuracy in urban and dense urban locations of within 2.3 to 3.4 meters, respectively, for 80 percent of fixes in the 2012 testing,[25] and showed vertical location accuracy in urban and dense urban locations of within 2.2 to 3.2 meters, respectively, for

[25] *See Third Further Notice*, ¶ 71 (*citing CSRIC Indoor Location Test Bed Report* at 39) (referencing NextNav's z-axis results from 2012 CSRIC testing).

80 percent of fixes in subsequent tests conducted in 2013.[26] This is entirely consistent with the vertical location test results for these same morphologies that were documented in the Stage Z test report, albeit demonstrating continuing improvement in NextNav's technology, now achieving 1.5 meter accuracy for urban and 2.5 meter accuracy for dense urban for 80 percent of wireless calls.

Table 2. NextNav Vertical Test Results for 80% of Calls (in meters)

Testing Event	Dense Urban	Urban	Suburban
Stage Z Test Bed (Feb. 2018)	2.5	1.5	2.0
MBS Rev 2 Tests (June-July 2013)	3.2	2.2	2.3
CSRIC III Tests (Dec. 2012)	3.4	2.3	5.0

Therefore, given the high level of consistency in the data that is documented in the Stage Z test report, it is reasonable to conclude that the data produced in the Stage Z test process is sufficient and no additional testing is necessary or appropriate.

B. The Test Data from the Report Can be Used to Reliably Anticipate the Performance of Vendors, Location Technologies, and Mobile Devices that Were Not Tested

The Stage Z test bed results clearly document that it is technically feasible to identify the floor level of wireless callers to E911 for a very high percentage of the wireless calls. Further, the technology employed by NextNav does not involve any proprietary equipment, relying instead on barometric pressure sensors that are already installed in wireless handsets and a network of weather stations for compensation. Therefore, it is reasonable to conclude that other vendors could replicate the floor level accuracy results that were documented in the Stage Z test bed.

[26] *See generally NextNav Aug. 14, 2013 Ex Parte Letter* (providing results of NextNav's Rev.2 indoor location testing and comparing them with the accuracy of NextNav's z-axis results from the CSRIC Indoor Location Test Bed).

It is also reasonable to conclude that other technologies—*i.e.*, those that do not rely on barometric pressure sensors—could also provide vertical floor level information. In several recent filings, the wireless carriers have cited the possibility of using 3D Wi-Fi,[27] Bluetooth beacons[28] and other technologies to determine the vertical location of a wireless caller. It can therefore be anticipated that a greater and greater number of technologies will soon be able to deliver z-axis capabilities.

All this said, it is entirely unnecessary for the Commission to reach a conclusion regarding the capabilities of location technologies that do not employ barometric pressure sensors. Instead, it is sufficient for the Commission to conclude that indoor location technologies do exist that can provide vertical floor level accuracy for wireless callers and that multiple vendors have—and additional vendors could—make these technologies available for use by the major wireless carriers in major cities throughout the United States. The results of the Stage Z test bed clearly justifies this conclusion.

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[27] *See* Verizon – Indoor 911 Location Accuracy Second Progress Report, PS Docket Np. 07-114, at 5 (Aug. 3, 2018) (explaining that a few vendors of the 3D Wi-Fi positioning approach have indicated the availability of their z-axis solutions for testing within the next 12 months).

[28] *See* Letter from Joseph P. Marx, Assistant Vice President, AT&T Services, Inc., to Marlene H. Dortch, Secretary, Federal Communications Commission, at 6 (Aug. 3, 2018) (indicating that the NEAD LLC has engaged diverse group of reference point owners to meet FCC reference point requirements, including Bluetooth beacon service providers, Internet Service Providers and large enterprises); T-Mobile's 36 Month Progress Report for Implementing the Federal Communication Commission's Forth Report and Order on Wireless E911 Location Accuracy Requirements, at 14 (Aug. 3, 2018) (explain as an example that T-Mobile has incorporated a requirement to handset manufacturers that devices coming in since mid-2018 have the capability to turn on Wi-Fi and Bluetooth capabilities when placing a 911 call); Letter from Ray Rothermel, Counsel-Legal/Government affairs, Sprint Corporation, to Marlene H. Dortch, Secretary, Federal Communications Commission, at 2 (Aug. 3, 2018) (explaining that Sprint is leveraging existing and evolving wireless technologies, such as Wi-Fi and Bluetooth, to help improve the ability of first responders to locate wireless 9- 1-1 callers that may be indoors).

C. The Report Provides Accurate Information Regarding the Performance of Barometric Sensor Technologies in Real World Environments

In assessing the results of the z-axis test bed, it is important to note that the individual barometric pressure sensors that were used in the Stage Z test process were not specially selected for this purpose. Instead, the barometric pressure sensors were already installed in each of the wireless handsets during the normal mass market manufacturing process for those consumer devices. Therefore, no basis exists to suggest that the pressure sensors might function differently in real world environments.

Indeed, the z-axis tests *were* conducted in real world environments. The test locations that were selected by the independent test bed administrator in San Francisco and Atlanta included a wide range of morphologies and indoor environments that were intended to replicate the conditions that would exist for actual consumers using their personal wireless handsets in emergency situations. Therefore, it is reasonable and appropriate to conclude that the Stage Z Report provides accurate information regarding the performance that can be expected of barometric pressure sensors in real world conditions.

CTIA raised concern that, although commercially-available handsets were used in the z-axis test bed, they were supplemented with additional software to replicate the capabilities of the NextNav and Polaris solutions.[29] CTIA explained that "[n]o actual calls were placed to produce any z-axis fixes, and standardized 9-1-1 signaling was not used."[30] It must be noted, however, that the appropriate signaling to support barometric based altitude determination from the device to the network is already standardized in 3GPP (Rel 13/14) and OMA. As such, all elements required to

[29] *CTIA Letter* at 4.

[30] *Id.*

commercially scale either solution exist today and simply need carrier and device manufacturer support to include appropriate calibration software within new handsets. Thus, real world conditions were reflected adequately in the Stage Z test process and no further testing is necessary.

D. The Barometric Sensor Technologies that Were Tested are Commercially Available and Already Installed in Mass Marketed Mobile Devices

As noted above, the barometric pressure sensors that were used in the test process were never touched by either NextNav or Polaris. Instead, they were already installed in each of the wireless handsets during the normal mass market manufacturing process for those consumer devices. The sensors are commercially available and widely in use by handset manufacturers. In fact, the Commission's *Fourth Report and Order* acknowledged that, even by the time the *Third Further Notice* had been released in 2013, "nearly all smartphones had been equipped with sensors that can determine speed, compass direction, and movement, and in some cases, height above sea level."[31] The Commission also acknowledged the comments of Bosch Sensortec, a leading international supplier of sensors, which noted that the large volume of barometric sensors being produced has resulted in significant economies of scale, which it then estimated would drive the per-unit cost downward.[32]

Other location technology vendors have also recognized the ability to use barometric pressure sensors or other solutions for vertical location calculation. TruePosition previously explained to the Commission that "there is no question that technology is available to meet the

[31] *Fourth Report and Order*¸ ¶ 105 (*citing Third Further Notice,* ¶ 79, *further citing* Lawson, Stephen, "Ten Ways your Smartphone Knows Where You Are," PC WORLD (Apr. 6, 2012)).

[32] Comments of Bosch Sensortec, PS Docket No. 07-114, at 6 (May 12, 2014).

FCC's proposed [vertical accuracy] standards."[33] iPosi confirmed that "[h]igh quality, low cost [barometric] based sensors now are in major brands of mobile devices and can provide excellent relative accuracy (that is, the on-board sensor can accurately detect a change in mobile elevation with precise [sic] of less than a meter)."[34] Given these facts, the Commission can reasonably conclude that barometric pressure sensors are now, and will continue to be, widely available and affordable for manufacturers of wireless handsets.

II. THE CARRIERS' PROPOSED FIVE METER Z-AXIS METRIC IS NOT SUPPORTED BY THE STAGE Z TEST RESULTS AND IS INSUFFICIENT TO PROVIDE FLOOR LEVEL ACCURACY

When the Commission agreed to use the carriers' Roadmap as the basis for its *Fourth Report and Order*, it did so in part because the Roadmap affirmed "the importance and need for floor-level location information to be provided to emergency responders."[35] The carriers' recent proposal for a 5 meter z-axis metric, however, clearly abandons their previous commitment to floor level accuracy. This is a critical failing.

As the Commission has previously concluded, a 3 meter vertical accuracy metric is necessary to provide floor level information and the use of "[a] vertical search ring greater than 3 meters from the caller could lead to mistaken floor identification."[36] The importance of floor level

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[33] Comments of TruePosition, PS Docket No. 07-114, at 16 (May 14, 2014).

[34] Comments of iPosi, PS Docket No. 07-114, at 15-16 (May 12, 2014).

[35] *Fourth Report and Order*, ¶ 112.

[36] *Id.* The Commission observed that average floor height of a multi-story building floor is 3.1 meters in residential buildings, 3.9 meters in office buildings, and 3.5 meters in mixed-use settings. *See* Council on Tall Building and Urban Habitat, Height Calculator, *available at* http://www.ctbuh.org/TallBuildings/HeightStatistics/HeightCalculator/tabid/1007/language/en-GB/Default.aspx (*last visited* Sept. 18, 2018).

information to public safety has been thoroughly documented for nearly a decade in this proceeding. The Public Safety Foreword of the CSRIC Test Bed Report explains that "floor level vertical accuracy is valuable in large multi-story structures common in urban and dense urban morphologies."[37] As NENA also explained at the time, a 3 meter vertical accuracy requirement (coupled with a 50 meter horizontal requirement) would "dramatically improve the ability of public safety agencies to identify the building and floor from which a wireless 9-1-1 call originates."[38]

As a specific example, in 2014, NextNav provided its vertical location handset technology to public safety representatives in San Francisco to conduct dispatch trials in multi-story structures, specifically utilizing CSRIC-tested buildings to examine the relative ability of first responders to find a caller with and without vertical information. As would be intuitively obvious, these test results revealed significant improvements in search time when floor level vertical information was available to the first responder.[39]

In stark contrast, a vertical location metric of +/-5 meters, could place emergency first responders as much as two floors above or below a wireless caller in distress, resulting in a total search area of five floors. In a large commercial building, this could create a significant challenge to reaching an individual in distress in time to be of assistance.

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[37] *CSRIC Indoor Location Test Bed Report* at 9.

[38] Comments of NENA, the E9-1-1 Association, WT Docket No. 11-49, at 14 (March 22, 2013).

[39] Letter from San Francisco Public Safety Organizations to Marlene H. Dortch, Secretary, Federal Communications Commission, PS Docket No. 07-114, at 2 (July 14, 2014) (providing test results showing that vertical location information can make locating of callers in dense urban environments between two and ten times faster).

Although the major wireless carriers do not explain the specific basis for their +/-5 meter proposal, it is likely based primarily on the z-axis test results for Polaris' location technology, which were listed in the Stage Z Report at 4.8 meters or less for 80 percent of calls.[40] Polaris has separately indicated, however, that it intends to employ active sensor bias compensation in real world conditions, which, Polaris reports, will improve its vertical location capabilities.[41] Therefore, no justification exists to adopt a vertical metric that is based on Polaris' uncompensated test results.

Instead, given the critical need for floor level vertical location accuracy, and the documented test data demonstrating that these capabilities are readily available, the Commission should reject the proposal of the wireless carriers for a vertical location metric of +/-5 meters and instead adopt the Commission's original and well supported proposal for a vertical floor level metric of +/-3 meters for 80 percent of wireless calls to E911 emergency services.

III. THE COMMISSION IS JUSTIFIED IN ADOPTING A Z-AXIS METRIC WHILE FURTHER VERTICAL LOCATION TESTING IS CONDUCTED

The Commission's *Fourth Report and Order* gave the major wireless carrier more than three years to conduct independent testing to develop a proposed z-axis accuracy metric and to submit the proposed metric to the Commission for approval.[42] Given the carriers' previous experience with conducting independent test beds, the three years provided by the Commission was arguably more than adequate. Nevertheless, the carriers waited until less than a year before

[40] *See Stage Z Report* at 120.

[41] *See id.* at 133-134.

[42] *See Fourth Report and Order*, ¶ 116.

the deadline to organize the test bed and are now requesting that the Commission give them additional time to conduct even more z-axis testing.

NextNav fully supports the proposal of the wireless carriers to conduct additional z-axis testing. Such testing will be needed as additional types of vertical location technologies become available for evaluation in a test bed.[43] Nevertheless, the Commission should not delay in setting a z-axis metric while further testing is conducted. Any such delay would likely be harmful to public safety because it would place into question whether the major wireless carriers would have sufficient time to comply with the adopted z-axis metric by the 2021 and 2023 deadlines for the top 25 and top 50 CMAs, respectively. Instead, the Commission should immediately adopt a floor level metric of +/-3 meters for 80 percent of calls and allow the carriers to conduct further z-axis testing in order to identify additional technologies (beyond those that have already been tested) that can reliably achieve this vertical location capability. This is the same approach the Commission took in the *Fourth Report and Order*, which adopted both a horizontal accuracy metric and set the deadlines for deployment, while allowing the carriers to continue to evaluate different technologies that could achieve these capabilities. In fact, when the 50 meter horizontal accuracy metric was established in 2015, test results at the time did not reflect any commercially implemented technology capable of meeting the 2021 accuracy metric for 80 percent of calls. Therefore, the Commission is now even further justified in adopting a 3 meter vertical metric based on the Stage Z test results that have already been documented.

[43] In a subsequent section of these comments, NextNav addresses some of the parameters that should be addressed in subsequent testing of newer technologies.

A. Further Z-Axis Testing in Extreme Weather Conditions is Unnecessary

The wireless carriers have argued that additional z-axis testing is needed to determine the potential effects of extremely cold weather.[44] The z-axis testing in Atlanta, however, was conducted during a significantly cold period for that city. Most importantly, the Stage Z Report notes that while "extreme weather" and "every possible indoor environment" were not encountered, the Report states unequivocally that the test results do reflect a "reasonably comprehensive" selection of regions, buildings, test points and weather conditions.[45] The Report further acknowledges that material variations in performance were *not* noted among different regions, or for that matter, among varying morphologies within regions.[46]

In the end analysis, none of the testing regimes that have been undertaken by CTIA have fully covered every possible environment and use case, nor every configuration of building type, construction environment or region of the country. Atlanta and San Francisco, along with a handful of representative buildings in each morphology, were deemed sufficient to adequately characterize the likely performance of horizontal location technologies in Stage 1 and Stage 2 testing. CTIA's Stage Z testing, as delineated in the Report, also did a "reasonably comprehensive" job of testing and characterizing the performance of vertical location technologies, and provides an appropriate technical basis upon which the Commission can finalize its vertical accuracy metric.

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[44] *Fourth Report and Order*, ¶ 116.

[45] *See Stage Z Report* at 3.

[46] *See id.* at 100.

B. Further Z-Axis Testing of Time-of-Day Indoor Fluctuations is Unnecessary

All vertical location technologies that rely on the use of barometric pressure sensors must correct for two critical variables in their performance—changes to outdoor air pressure caused by weather and changes to indoor air pressure caused by HVAC cycling and other man-made conditions. As the Report notes, changes to outdoor air pressure were addressed effectively by NextNav through a managed barometric pressure network. Varying changes to indoor air pressure can also be addressed by vertical location technology vendors. As depicted in the two figures below, these man-made changes to indoor air pressure can produce regular cycles throughout the day, but have relatively modest impacts on vertical location accuracy and are reasonably contained within a vertical error budget of 3 meters for 80 percent of fixes.

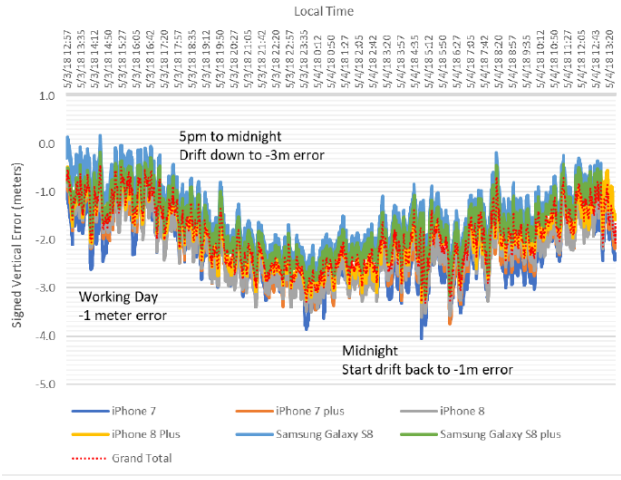


Figure 9.38 – Atlanta 24-hour Collect Signed Vertical Error vs. Time – NextNav devices

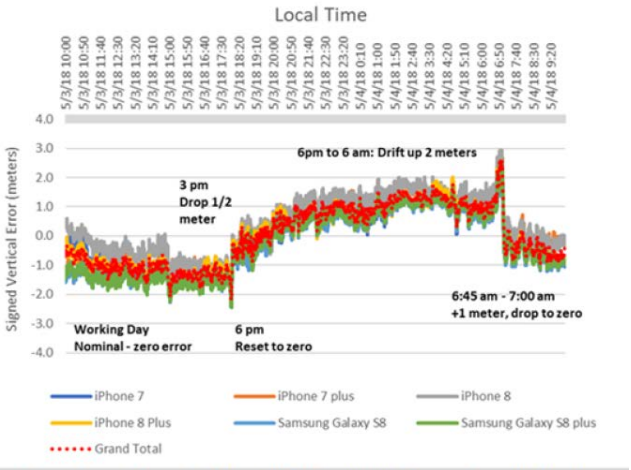


Figure 9.36 – San Francisco 24-hour Collect Signed Vertical Error vs. Time – NextNav devices

Figures 5 & 6. NextNav 24 Hour Vertical Test Results in Atlanta and San Francisco

CTIA argues that the modest indoor pressure variations identified in the figures above could potentially be *additive* to the observed errors that are already documented in the test results.[47] However, the normal test process *itself* involved various times of the day, in differing HVAC

[47] *See id.* at 103.

cycles and weather and temperature conditions, such that much of the time-of-day and weather fluctuation is *already* captured within the body of the test results. Further, the Report notes that performance variations among different morphologies and building construction types, each of which constitute different HVAC and building environmental systems, were minimal. Therefore, no need exists to conduct additional testing to further document the time-of-day impact of man-made pressure fluctuations inside buildings.

C. Further Z-Axis Testing of Additional Device Types or Operating Systems Is Unnecessary

The Stage Z testing included several different models of the most popular wireless handsets on the market, including older models of these devices. The core functionality of the vertical location capability within all of these wireless handsets was the barometric pressure sensor included in the device, not its operating system or other components. Therefore, no need exists to conduct additional testing with other handset brands or operating systems.

CTIA argues that additional testing may be needed to assess the vertical location capabilities of older wireless handsets, arguing that the accuracy of barometric pressure sensors degrades with age.[48] The recent z-axis test process, however, employed both older (2016) and newer handsets and identified no degradation in location capabilities for the older devices as indicated in Figure 7 below. Further, given the churn rates of wireless handsets by consumers, it seems unnecessary to test significantly older handsets since they are unlikely to remain in use by consumers in substantial numbers by the 2021 and 2023 implementation timeframes specified in the *Fourth Report and Order*.

[48] *See CTIA Letter* at 3-4.

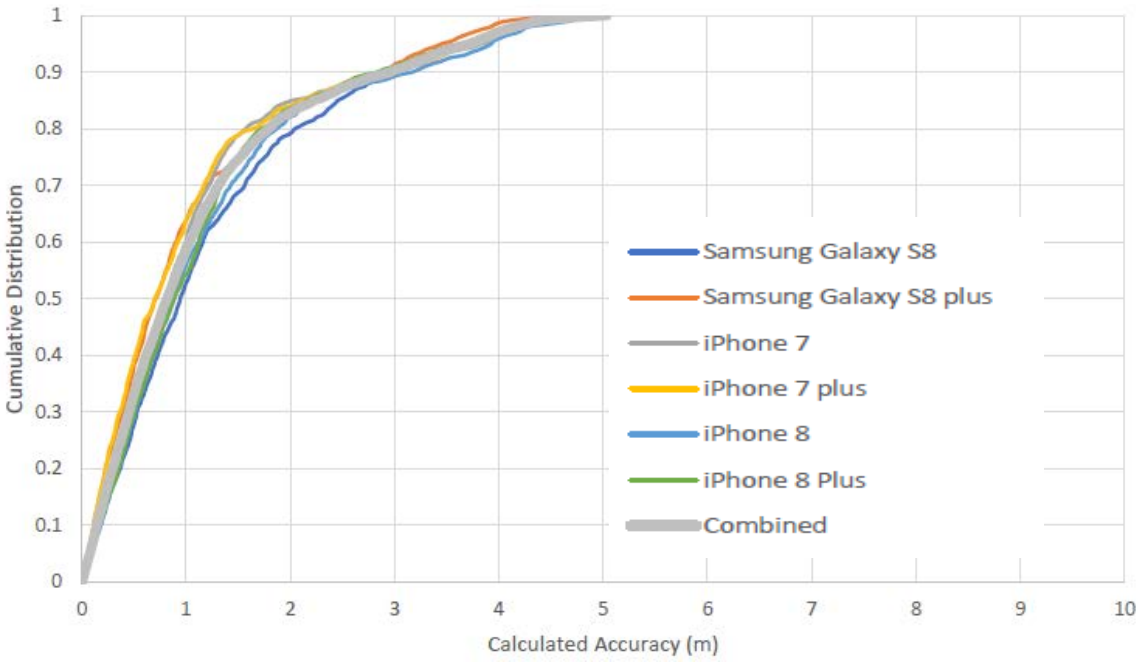


Figure 7. NextNav Vertical Results by Handset in Dense Urban Morphology

Instead, the handsets that were employed in the Stage Z test bed were appropriately representative of those that are widely used by consumers and no justification exists to claim that the substitution of other handset brands or operating systems would result in material changes to the test results. Therefore, the Commission should adopt its proposed 3 meter vertical metric and reject calls for further testing prior to its implementation.

D. Further Z-Axis Testing in Additional Geographic Locations is Unnecessary

As discussed in previous sections of these comments, no need exists to test in additional geographic locations. NextNav's MBS technology was tested in the Atlanta and the San Francisco Bay Area (including San Jose), the same markets CTIA has used for prior Stage 1 and Stage 2 horizontal location accuracy testing. Polaris' technology was tested in each of these cities as well as in Chicago.[49] These cities diverge widely with respect to the age and type of structures,

[49] NextNav was unable to participate in the Chicago z-axis test process because an actual decision to conduct testing in Chicago was not announced by the carriers until September 2017, with the testing then scheduled for November 2017, providing insufficient time for NextNav to deploy its

employing widely different construction materials and reflecting widely different urban street patterns, both between the different cities and within them. Despite these significant differences, the z-axis test results for both NextNav and Polaris were very consistent, as indicated in Figures 1 and 2 above. Therefore, no need exists to create substantial further delay in this process by conducting z-axis testing in yet additional cities or regions.

Finally, CTIA has argued that additional testing is needed because NextNav was not able to participate in the rural environments selected for the z-axis test bed.[50] NextNav's MBS technology was tested for vertical accuracy in rural areas during the original CSRIC III test bed conducted in the winter of 2012. During that test process, a total of 820 calls were placed from rural locations and, as indicated in Table 3 below, NextNav's results for those calls fell fully within an accuracy level of 3 meters for 80 percent of all calls.[51]

Table 3. NextNav 2012 CSRIC III Vertical Test Results in Rural Areas

Percentage of the 820 Placed Calls	Vertical Distance (in meters)
67th Percentile	0.7
80th Percentile	0.9
90th Percentile	1.1

In any event, it is unclear what benefit would result from additional z-axis testing in rural areas. The Commission's location accuracy rules require wireless carriers to deploy z-axis

network in that market. The fact that the tests were subsequently delayed until February 2018 did not provide additional time for NextNav because, by the time the delays became apparent, it was already too late to begin constructing NextNav's network in advance of the February test dates.

[50] *See CTIA Letter* at 3.

[51] *See CSRIC Indoor Location Test Bed Report* at 36-37.

capabilities only in the top 50 CMAs, outside of which the presence of high-rise structures is not as significant, making a rural z-axis solution arguably not as critical.

E. Further Z-Axis Testing Using Technologies that Do Not Employ Barometric Pressure Sensors is Unnecessary

Finally, prior to the adoption of a z-axis metric, no need exists to conduct z-axis testing using location technologies that do not employ barometric pressure sensors. Although such technologies are under development, their immediate availability for use is not necessary for the Commission to set the metric for vertical location capabilities in the top CMAs by the 2021 and 2023 deadlines. Instead, it is sufficient for the Commission to conclude that multiple vendors have developed and have successfully tested vertical location technologies using barometric sensor technologies that can achieve floor level vertical accuracy and that these technologies are available for use by wireless carriers.

Further, the Commission has already provided the carriers alternate technical approaches to meet their vertical location requirements, such as by implementing address-based dispatchable location technologies using the National Emergency Address Database ("NEAD"). The fact that additional technical approaches are under development and may provide wireless carriers still further options in the future does not constitute a reason to wait for the deployment and testing of these different approaches before establishing an accuracy metric. Instead, the critical public safety need for the immediate implementation of vertical location accuracy requirements to assist wireless callers in distress obligates the Commission to adhere to its 2021 and 2023 deadlines for the implementation of vertical location capabilities in the top 50 CMAs in the United States.

IV. THE COMMISSION SHOULD REQUIRE CARRIERS TO CONDUCT Z-AXIS TESTING ON ANY ADDITIONAL VERTICAL LOCATION TECHNOLOGIES THAT BECOME AVAILABLE

As noted previously, NextNav agrees with the major wireless carriers that further z-axis testing of indoor location technologies will be necessary to identify those technologies that are capable of providing the necessary floor level accuracy. The parameters of such testing should be considered in two categories. First, any additional vertical location vendors that employ barometric sensor-based solutions should be tested in the same manner as the Stage Z test bed, but should use different buildings and test points. As the Stage Z Report acknowledges, the z-axis test process involved a "reasonably comprehensive" selection of regions, buildings, test points and weather conditions.[52] The test process also considered specific variables that are relevant to barometric pressure sensors, such as variations in outdoor and indoor air pressure.

In contrast, the z-axis test process for vertical location technologies that do not employ barometric pressure sensors will need to account for other critical variables. For example, the assessment of any vertical location technology that is reliant on a registered database of consumer devices—such as fingerprinting, 3D or crowd-sourcing Wi-Fi or Bluetooth signals—will need to consider whether there is sufficient density of Wi-Fi/Bluetooth access points in three dimensions to reliable determine the altitude and floor level. The test process should also consider the power levels, angles of arrival, and other relevant elements required to determine altitude and floor levels in different types of buildings and between socioeconomic groups. In addition, the tested capabilities of such location technologies can vary dramatically if the test buildings are known and surveyed in advance (even if individual test points within the buildings are different). In order for

[52] *See Stage Z Report* at 3.

the z-axis test process to adequately account for such factors, z-axis test buildings should be selected either randomly or using a selection process that involves other locations that have not previously been used in the several rounds of testing that have been conducted in recent years.

Other variables and uncertainties will likely also be relevant to the vertical location testing of non-barometric based technologies. It would therefore be appropriate for the Commission to request that ATIS or CTIA's Z-Axis Working Group study the technologies and develop an appropriate testing regimen for non-barometric based technologies, just as they did for the testing of barometric-based solutions to ensure the requirements of public safety are met. Further, the results of any such additional testing of barometric based or non-barometric based technologies should be made public for comment.

Vertical location testing of technologies that rely on databases of registered devices will also need to consider whether the accuracy of the information contained in such databases will remain reliable over time as previously-registered devices are moved or discarded. This may require periodic retesting of the vertical location capabilities of such technologies. Fortunately, the *Fourth Report and Order* already requires the disclosure of live call data by wireless carriers on a quarterly basis in six major cities.[53] Thus, a program of periodic retesting may supplement the live call test data in identifying any changes over time in the accuracy of location technologies that rely on database solutions.

V. CONCLUSION

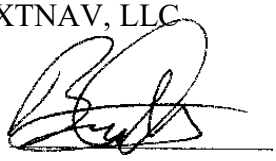
The results of the recently concluded Stage Z test bed, combined with the results of three previous rounds of tests conducted by CTIA, CSRIC and other independent and expert

[53] *See* 47 C.F.R. § 20.18(i)(3)(ii)(B) and (C).

administrators clearly demonstrate that technologies are available today (and others are being developed) that can provide floor level vertical accuracy of within 3 meters for at least 80 percent of wireless calls. The public safety community has clearly communicated its desire for floor level vertical accuracy in major cities, and the body of independent test results over the past six years demonstrates that such accuracy is clearly achievable. Therefore, the Commission should adopt a vertical location metric of +/-3 meters for 80 percent of calls and direct the major wireless carriers to implement these capabilities by April 2021 in the top 25 CMAs and by April 2023 in the top 50 CMAs. The adoption of a clearly delineated vertical accuracy requirement to supplement the dispatchable location approach to locating wireless callers in distress will expedite the availability of this important public safety capability.

Respectfully submitted,

NEXTNAV, LLC

By: 

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